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Talk to be presented by Mr. Pesman at the Annual Meeting of the Armed Forces National Research Council Committee on Hearing, Bioacoustics and Biomechanics (CHABA) on October 10, 1963.

OPERATIONAL VIBRATION ENVIRONMENTS IN SPACE VEHICLES

An appraisal of the physiological significance of vibration requires that we have in hand two main bodies of data; the general characteristics of the vibration stress, and the stresses that can be endured without injury or without destroying the crews' abilities to perform their tasks. This discussion will deal primarily with the first body of information.

Spacecraft vibration arises from several different sources. The rocket engines and their associated rotating machinery produce both longitudinal and lateral vibration that is predominant during launch periods. The rocket attitude control system is another source of lateral vibration. The third general source of vibration is aerodynamic instability, or buffeting, caused by atmospheric disturbances such as wind shears in going from one level of the atmosphere to another. Onboard rotating machinery can produce vibration throughout a mission.

The first slide,

MAY WE HAVE SLIDE ONE PLEASE

is an example of a typical vibration record. This record shows the pitch bending vibration for three positions on the spacecraft; the nose cone, the fuel tank, and the thrust ring. Each individual record shows the acceleration in meters per second per second plotted against the time from lift-off. One meter per second per second is approximately equal to one-tenth of a g; thus, the numbers represent approximately tenths of g's. Since these records are the combined linear acceleration in the pitch direction with the superimposed vibration, the long duration trends of the record show the rocket acceleration that results from the gimbaling of the engines in controlling the rocket attitude. The high frequency shuddering superimposed on the general trends of the record indicates the superimposed vibration. A rapid inspection of the records shows that the maximum sustained acceleration is approximately two-tenths of a g. The vibration is seldom greater than approximately plus or minus one-tenth of a g.

It is readily apparent that little can be learned from records in this form except for the general magnitude of the accelerations. Additional information must be obtained by further processing and analysis.

Since various parts of the body have various frequencies, information concerning the magnitudes of the acceleration in particular frequency bands would be useful. Such information is presented on the second slide.

MAY WE HAVE SLIDE TWO PLEASE

This slide shows the magnitude of the acceleration in 3 different frequency bands for the longitudinal direction of a vehicle. In this case the root mean square average has been plotted against the elapsed time from launch in seconds. Here you can see that the average acceleration in the 0.5 to 37.5 cycle per second band was approximately one-half g at approximately 65 seconds after launch. In the 37.5 to 75 cycle per second band, the maximum acceleration was approximately one-half g. In the 75 to 150 cycle per second band, the maximum acceleration reaches approximately nine-tenths of a g.

The next slide,

MAY WE HAVE SLIDE THREE PLEASE

shows similar data for the radial acceleration. This vibration acceleration is perpendicular to the long axis of the rocket. You can see here maximum values of approximately $1\frac{1}{4}$, $1\frac{1}{2}$, and $1\frac{8}{10}$ g's for the three frequency bands.

The previous two slides presented data for only three frequency bands. Presenting vibration for a full spectrum of frequencies in this fashion becomes somewhat cumbersome because a separate graph must be available for each frequency band. For this reason vibration data is usually summarized by a figure such as shown on the next slide.

MAY WE HAVE SLIDE FOUR PLEASE

OPERATIONAL VIBRATION ENVIRONMENTS IN SPACE VEHICLES

This slide shows a summary of the longitudinal vibration. RMS g's are plotted against the one-third octave band frequencies. You can see here that the vibration ranges from less than three-tenths of a g, increasing gradually with frequency, to a maximum of three g's in the one-thousand-cycle per second band. The vibratory force then decreases to approximately one g as the vibration frequency increases from 1000 to 2000 cycles per second.

Considering g's or force alone, however, does not cover the entire situation. Since vibration acting in resonance with the natural frequency of various parts of the human body can inflict a series of blows, human resilient systems are sensitive to energy input as well as the maximum imposed force. For this reason it is necessary also to consider the energy input per unit time, or the power in the frequency bands that encompass the natural frequencies of human systems. In other words, we are interested in frequencies from 4 to 5 cycles per second up through at least 400 to 600 cycles per second. Such a power spectrum is shown by the next slide.

MAY WE HAVE SLIDE FIVE PLEASE

This slide shows the power spectrum for the lateral direction at the right hand trunnion of a rocket vehicle. In this graph the acceleration density in g squared per cycle per second (power parameter) is plotted against the vibration spectrum.

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The power parameter, g^2/cps, is proportional to the power input. You can see from this plot that the maximum power input would occur in the 200, 330, and 750 cycle per second frequencies. The maximum value shown here is approximately 0.085 g^2 per cycle per second. The overall vibration level was 3.02 g's average.

The next slide,

SLIDE SIX PLEASE

shows a similar analysis for the longitudinal axis of the same vehicle. In this case most of the power input lies in the 400 and 750 cycle per second frequencies. The overall vibration level was $3\text{-}\frac{1}{4}$ g's average. In this case the maximum longitudinal values for the power parameter was about 0.045.

The previous slides have shown typical examples of the vibration environments that have been encountered. It has not been possible in the time available, however, to make a comprehensive survey and summary of the vibration environments. We can, however, summarize the sort of vibration environments that will be encountered in the near future. The frequency range will vary from two up through at least a thousand cycles per second, the full range of frequencies encountered in human body dynamics. The magnitudes of the acceleration will range from 0 to 5 g's in the lower frequencies and from 0 to 10 g's in the higher frequencies.

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These vibrational accelerations can be combined with sustained acceleration up to 10 g's or more. The duration of the vibrations can vary from a few seconds to, in some cases, more than a minute and for vibration induced by onboard machinery could endure for the complete mission. Power densities, the g squared per cycle per second, of approximately one-tenth are encountered.

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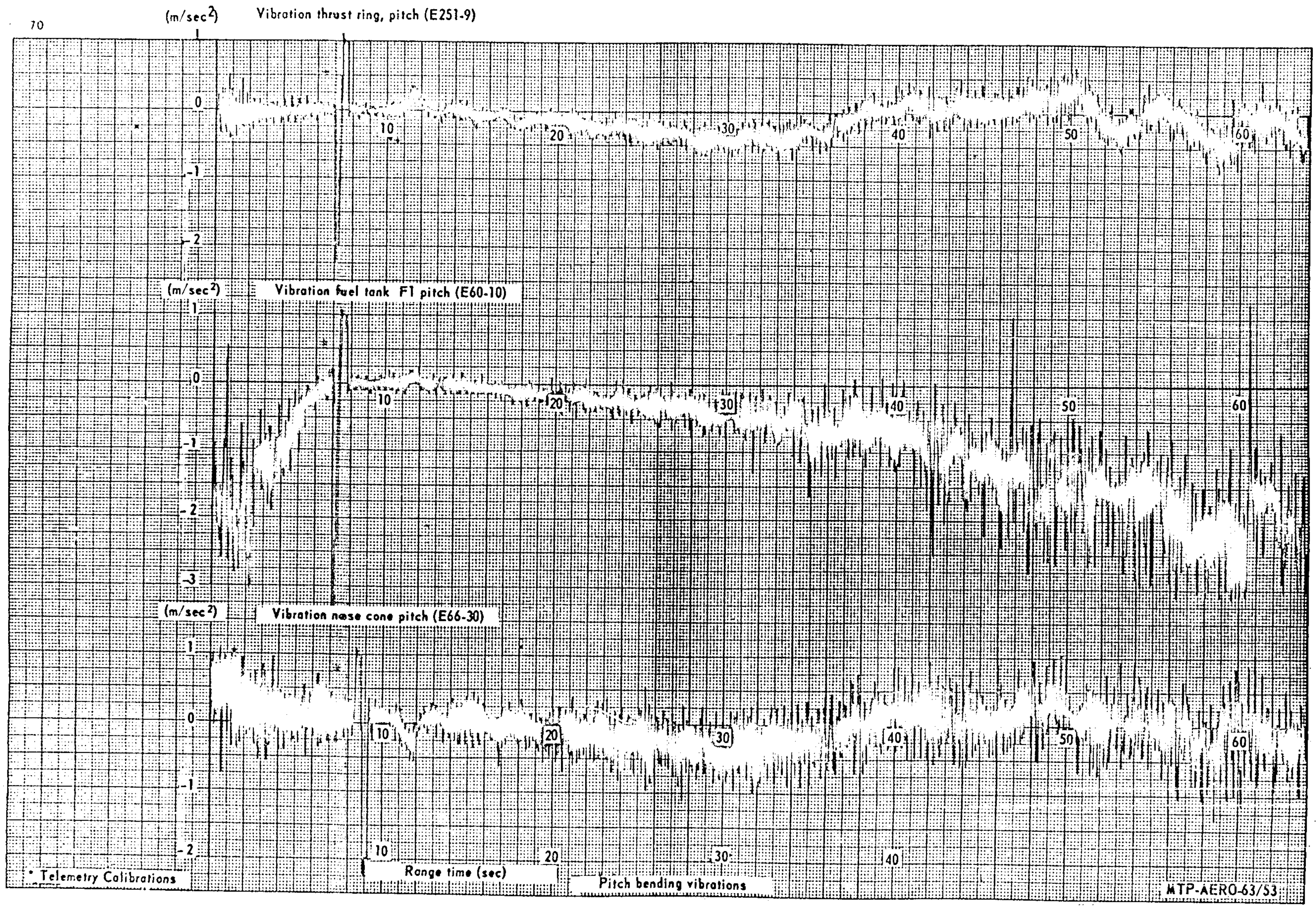
TYPICAL VIBRATION RECORD



Slide 1

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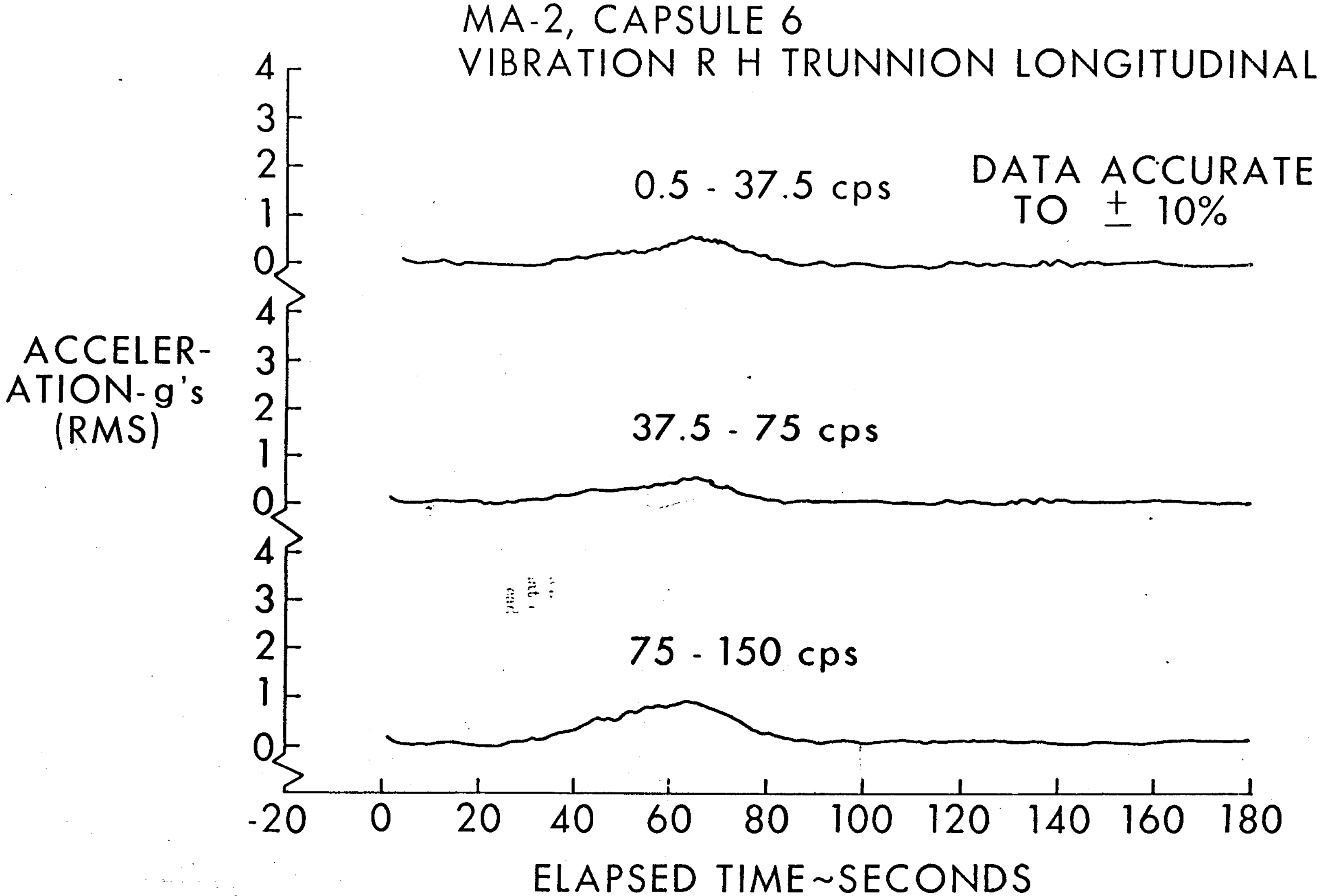
OCTAVE BAND TIME HISTORY



Slide 2

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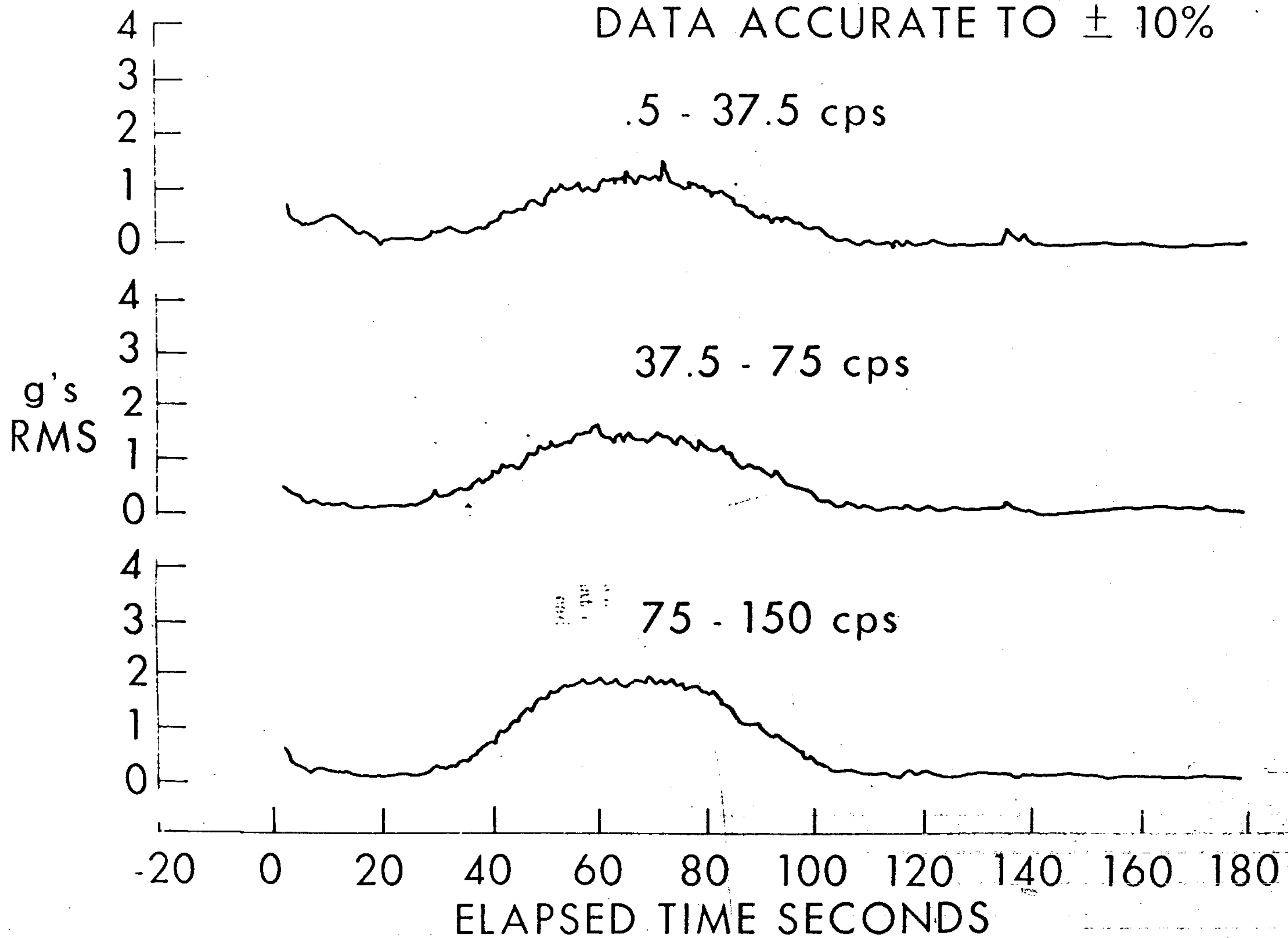
S-63-17763

OCTAVE BAND TIME HISTORY

MA-2, CAPSULE 6
VIBRATION R/H TRUNNION RADIAL
DATA ACCURATE TO ± 10%



Slide 3

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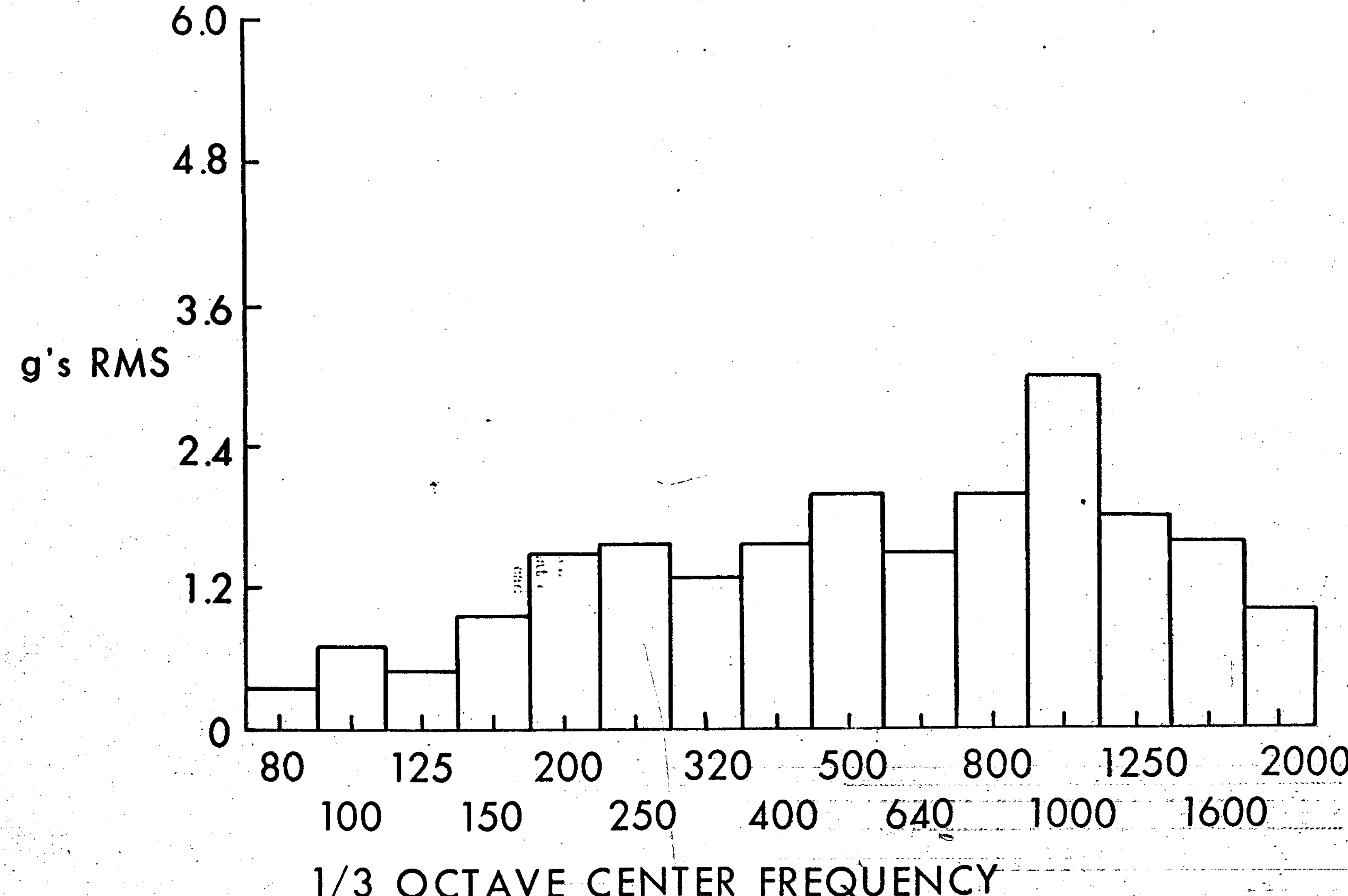
MA-3 ONE-THIRD OCTAVE BAND ANALYSIS LONGITUDINAL ACCELEROMETER Z-123



Slide 4

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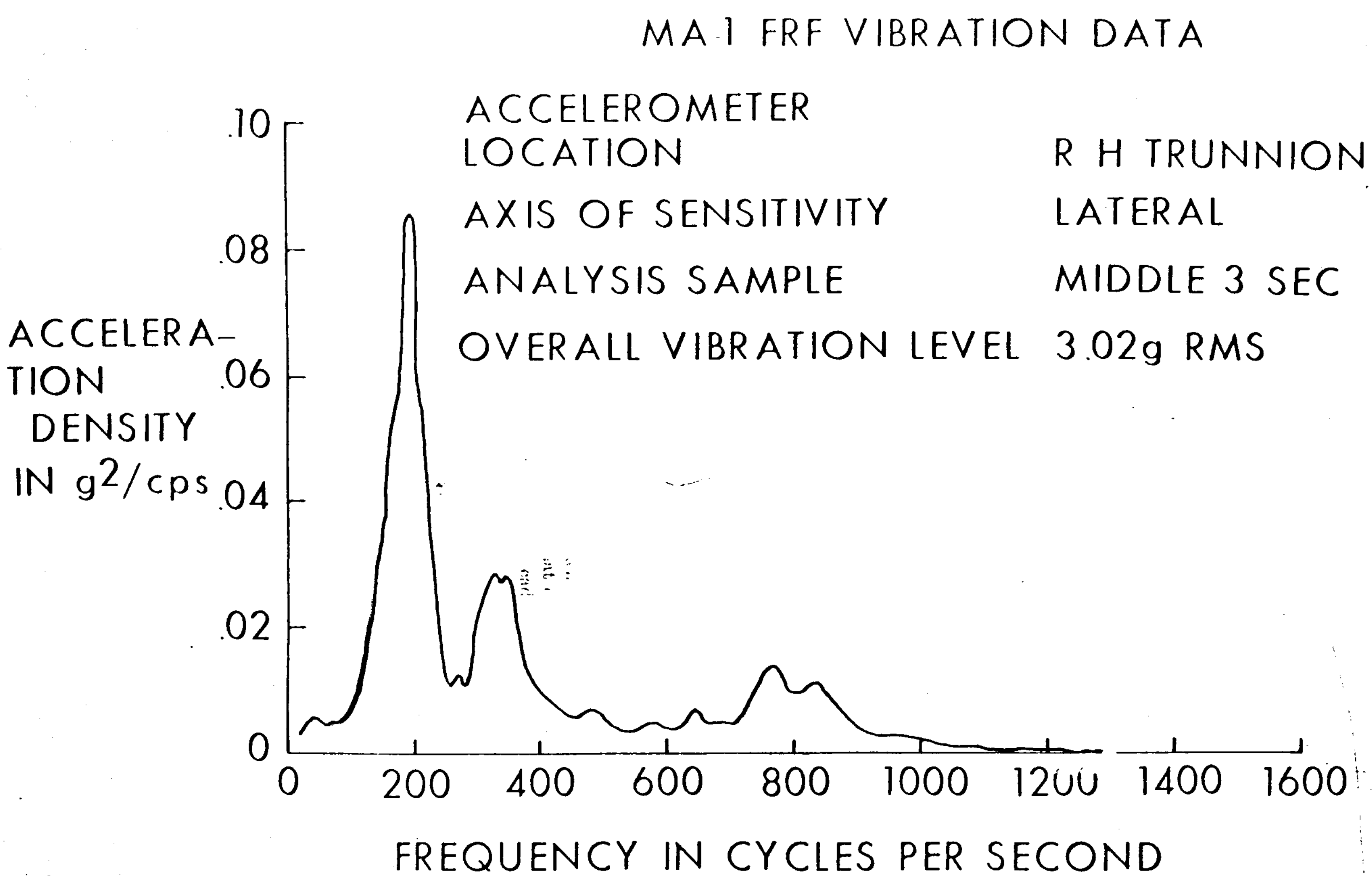
MA-1 CAPSULE LATERAL VIBRATION NEAR MIDDLE OF FRF (25 cps BANDWIDTH)



Slide 5

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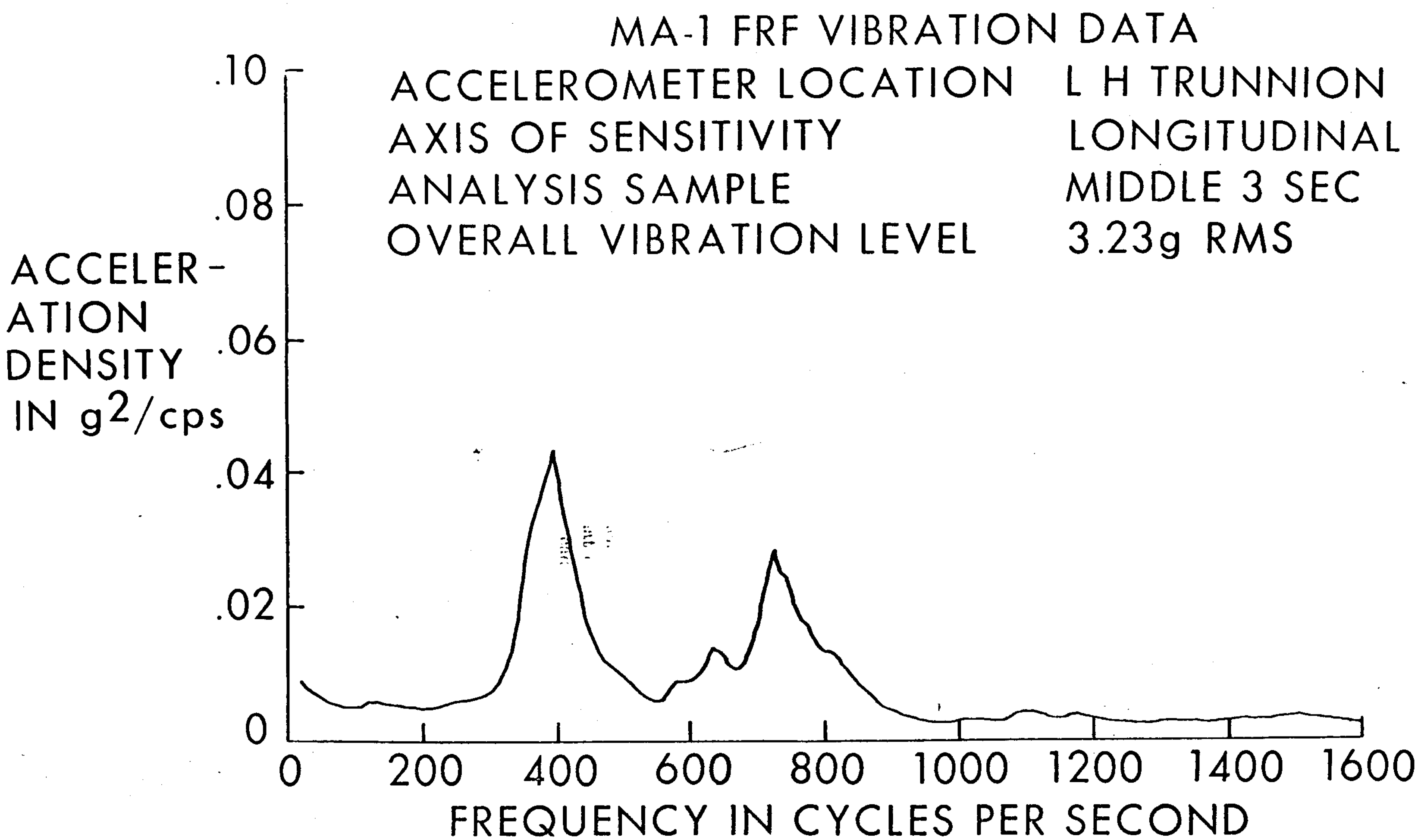
MA-1 CAPSULE LONGITUDINAL VIBRATION NEAR MIDDLE OF FRF (25 CPS BANDWIDTH)



Slide 6

NASA-MSC G PESMAN 1 OCT 63 S-299-20